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	Subsystem/Office Calorimeter Subsystem	
Document Title **Calorimeter CDE Light Yield Calibration**		

CHANGE HISTORY LOG

Revision	Effective Date	Description of Changes
1		Initial Release

1 Abstract

This document describes the procedure used at NRL to measure the light yield in the CsI(Tl) crystals with PIN diode readout. The procedure relies on calibrating the energy scale by depositing known amounts of energy in a crystal, either by nuclear line source or by cosmic ray muons and on calibrating the electronic gain by injecting known amounts of charge into the preamp.

2 Introduction

A reproducible method of measuring the absolute light yield (i.e. the number of electrons liberated from the PIN diode per MeV deposited in the CsI(Tl)) is required. The calorimeter CDE spec requires 5000 e/MeV in the large diode, and 800 e/MeV in the small diode, of the Hamamatsu S8576 PIN photodiode. We have used the following procedure to measure the light yield in prototype CDEs and small crystal samples.

3 Equipment List

The following items are required to measure the absolute light yield of a CDE.

1. One CDE, or one CsI(Tl) crystal with PIN photodiode attached.
2. One ^{228}Th source with sufficient activity (perhaps ~10 μCi). Alternatively, cosmic ray muons may be used, but if so, some method to define a collimated beam is required.
3. One ^{241}Am source with sufficient activity (perhaps ~1 μCi).
4. One detector housing to provide light tightness and EMI shielding.
5. Bias voltage supply, e.g. 45V C-Zn battery. For the EM PINs, bias of 65-70V is appropriate.
6. Charge-sensitive preamp with appropriate sensitivity, e.g. eV Products 5093.
7. Shaping amplifier, e.g. Mechtronics 519.
8. ADC, e.g. Canberra 8075 with parallel interface.
9. Data acquisition PC with parallel interface. Software, e.g. Homer.
10. Connectors, cables, etc.

4 Procedure

The following steps shall be followed.

4.1 Data Acquisition

Three data sets are required to measure the absolute light yield.

4.1.1 Measure electronic linearity and pedestal offset

Concept: To measure the pedestal and ensure that the readout electronics are linear, we inject pulses with a laboratory pulse generator into the front end at known amplitudes. The pulse amplitudes are chosen such that they bracket the pulse heights observed from the ^{241}Am and ^{228}Th photopeaks and the muon peak, if desired. The injected pulse shape is chosen to model the output of CsI(Tl) with modest fidelity. A simple linear model fit to the pulser peaks nearest the photopeaks should very closely model the spacing of the pulser peaks. The pedestal is given by the best-fit constant of the linear model.

NRL implementation: Set BNC 9010 to 10 mV amplitude, 100 Hz rep rate, tail pulse, 1 µs delay, 1 µs pulse width, 500 µs fall time, positive pulse. Inject pulses into Mechtronics shaper input. Accumulate 2000 pulses each at attenuation settings of unity, x2, x5, and x10. Find the locations of the x10, x5, and x2 peaks. Fit a linear model to the three peak locations, and define the best-fit offset to be the pedestal.

We note that at NRL we chose to inject pulses directly into the shaper, rather than the test input of the preamp. At the time this test procedure was developed, we were suspicious of the linearity and pedestal of the Mechtronics shapers. Thus the pulse shape was chosen to mimic a CsI(Tl) pulse from the output of the eV 5093 preamp. In hindsight, it would have been better to test the behavior of the preamp as well, model the output of the PIN, and inject the pulse into the test input of the preamp.

4.1.2 Measure signal from known energy deposition

Concept: In order to calibration the energy scale, we must deposit a known amount of energy in the CsI crystal. We can do this either with a nuclear line source or with muons. The typical light yield and electronic noise environment is such that the 2.6 MeV photopeak from ^{228}Th is readily detectable in the sum of the crystal ends for data collections of ~10 minutes. In single-end spectra, the photopeak is generally seen only as a shoulder, but the single-escape peak at 2.1 is detectable. Alternatively, sea-level muons may be used, but care must be taken either to allow only nearly vertically incident muons or to measure their pathlength through the CsI. A minimum-ionizing particle deposits 1.24 MeV cm^2 / g in CsI.

NRL implementation: Illuminate the center of the crystal with a ^{228}Th beam collimated to about 2 – 3 cm. Place the source ~50 cm from the crystal in a lead pig, with the collimator ~30 cm from the crystal. (These distances could both be decreased, but they are typical of the setup at NRL.) Orient the apparatus to prevent the collimated beam from striking anyone in the lab. With a survey meter, verify that the exposure to the user outside the collimated beam is <0.1 mR per hour at a distance of >30 cm from the source. Collect a spectrum for 20 minutes. Find the centroid of the photopeak or first escape peak. The energy scale (in units of MeV per ADC bin) is given by *MeV_per_bin = (2.1 MeV) / (first_escape_peak – pedestal)*.

4.1.3 Measure electronic gain

Concept: In order to calculate the electronic gain of the analog and digital front end, we must inject a known charge into the preamp and measure the output pulseheight. To do this, we illuminate the PIN with ^{241}Am and find the centroid of the 59.5 keV line. Because the energy to liberate an electron-hole pair in Si is 3.6 eV, a photoelectric interaction of the 59.5 keV X-ray in the Si will inject 16530 electrons into the preamp front end.

NRL implementation: Position a ~1 µCi ^{241}Am source directly behind the PIN diode under test. Accumulate a singles spectrum for 5 minutes. Find the centroid of the 59.5 keV line. The electronic gain (in units of electrons per ADC bin) is given by *e_per_bin = (59.5 keV / 3.6 eV/electron) / (Am_peak – pedestal)*.

4.2 Calculate light yield

The light yield *Y* (in units of electrons per MeV deposited) is given by *Y = e_per_bin / MeV_per_bin*, where the numerator and denominator were given above, *e_per_bin = (59.5 keV / 3.6 eV/electron) / (Am_peak – pedestal)*, and *MeV_per_bin = (2.1 MeV) / (first_escape_peak – pedestal)*.